ELSEVIER

Energy Policy 34 (2006) 3836–3846

ENERGY POLICY

www.elsevier.com/locate/enpol

Forecasting production of fossil fuel sources in Turkey using a comparative regression and ARIMA model ☆

Volkan Ş. Ediger[a], Sertaç Akar[b,*], Berkin Uğurlu[b]

[a]*Cumhurbaşkanlığı, Çankaya, 06689 Ankara, Turkey*

[b]*Middle East Technical University, Geological Engineering Department, İnönü Bulvarı, 06531 Ankara, Turkey*

Available online 19 October 2005

Abstract

This study aims at forecasting the most possible curve for domestic fossil fuel production of Turkey to help policy makers to develop policy implications for rapidly growing dependency problem on imported fossil fuels. The fossil fuel dependency problem is international in scope and context and Turkey is a typical example for emerging energy markets of the developing world. We developed a decision support system for forecasting fossil fuel production by applying a regression, ARIMA and SARIMA method to the historical data from 1950 to 2003 in a comparative manner. The method integrates each model by using some decision parameters related to goodness-of-fit and confidence interval, behavior of the curve, and reserves. Different forecasting models are proposed for different fossil fuel types. The best result is obtained for oil since the reserve classifications used it is much better defined them for the others. Our findings show that the fossil fuel production peak has already been reached; indicating the total fossil fuel production of the country will diminish and theoretically will end in 2038. However, production is expected to end in 2019 for hard coal, in 2024 for natural gas, in 2029 for oil and 2031 for asphaltite. The gap between the fossil fuel consumption and production is growing enormously and it reaches in 2030 to approximately twice of what it is in 2000.

Keywords: Fossil fuel production; ARIMA forecasting; Turkey

1. Introduction

It has been recently noted that three major problems of the Turkish energy system are: (1) dependency on imported energy sources, (2) domination of energy consumption by fossil fuels, and (3) low energy efficiencies compared to the other countries (Ediger, 2001, 2004; Çamdalı and Ediger, in press). It is obvious that the future accomplishment of Turkey, which has been one of the most successful countries in developing energy consumption capacity for last two decades (Ediger and Tatlıdil, 2002; Ediger, 2003), will depend on developing and implementing energy policies towards solving these problems.

These problems are also typical for a variety of countries in the world. The main energy sources that are used in such countries are usually imported fossil fuels in the form of oil, natural gas, and coal, and their need for fossil fuels increased enormously over the few decades. According to BP's (2004) data, fossil fuels consisted 88% of world's primary energy consumption in 2003. Among 61 countries, of which data is available, only 23 countries are self-sufficient in term of fossil fuel production, i.e. their domestic fossil fuel productions are equal to or higher than their fossil fuel consumptions. According to Ediger's (2003) primary energy consumer classes, 3 out of 4 Super and Major Consumers, 8 out of 11 Big Consumers, 8 out of 13 Medium Consumer, and 177 out of 191 Small Consumers are fossil fuel-poor countries. In other words, 196 out of 219 countries, consisting 89% of total, have fossil fuel production over fossil fuel consumption ratios lower than 1. The list of the countries, which are dependent on imported fossil fuel sources to meet their energy requirements are given in Table 1 (Ediger, 2003; BP, 2004).

☆The opinions and statements in this article are those of the authors alone and do not, in any way, reflect the official policy or position of their government or employer.

*Corresponding author.
E-mail address: asertac@metu.edu.tr (S. Akar).

0301-4215/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2005.08.023

Table 1
Fossil fuel-poor countries and primary energy consumer classes (Ediger, 2003; BP, 2004)

Classes	Share of world's total	Name of countries
Super [1/1][a]	>25.4%	USA (0.69)[b]
Major [2/3]	5.6–8.3%	China (0.91), Japan (0.26)
Big [8/11]	1.3–3.2%	Germany (0.36), India (0.76), France (0.08), Brazil (0.89), Italy (0.19), S. Korea (0.28), Ukraine (0.49), Spain (0.18)
Medium [8/13]	0.6–1.2%	Australia (0.95), S. Africa (0.79), The Netherlands (0.69), Poland (0.69), Taiwan (0.41), Turkey (0.21), Belgium (0.12), Thailand (0.50)
Small [177/191]	⩽0.5%	Sweden (0.12), Pakistan (0.56), Romania (0.71), Czech Republic (0.55), N. Korea, etc.

[a]Number of fossil fuel-poor countries and total is given in brackets.
[b]Ratio of fossil fuel production to consumption is given in parentheses.

Table 2
Basic statistics of fossil fuel production and consumption in Turkey from 1950 to 2003 (WEC TNC, 1986, 1990, 2003)

Million toe	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2003
Production (P)												
Fossil Fuel (FF)	2.026	2.813	3.429	5.549	8.259	9.127	8.641	12.914	15.819	15.941	16.763	13.992
Total (T)	6.426	7.819	9.403	11.623	14.516	16.473	17.358	21.935	25.478	26.719	26.855	23.965
FF/T Ratio	0.32	0.36	0.36	0.48	0.57	0.55	0.50	0.59	0.62	0.60	0.62	0.58
Consumption (C)												
Fossil Fuel (FF)	2.518	3.947	5.096	7.831	12.615	20.083	23.140	30.192	43.391	52.960	70.872	75.412
Total (T)	6.917	8.954	11.070	13.905	18.872	27.437	31.973	39.399	52.987	63.679	81.251	85.435
FF/T Ratio	0.36	0.44	0.46	0.56	0.67	0.73	0.72	0.77	0.82	0.83	0.87	0.88
P/C Ratio												
Fossil Fuel (FF)	0.80	0.71	0.67	0.71	0.65	0.45	0.37	0.43	0.36	0.30	0.24	0.19
Total (T)	0.93	0.87	0.85	0.84	0.77	0.60	0.54	0.56	0.48	0.42	0.33	0.28

The problem is crucial also for the European Union that approved to initiate accession negotiations with Turkey. The Union's economy is primarily based on fossil fuels, which make up four-fifths of its total energy consumption and almost two-thirds of its imports. The Green Paper COM(2002)321 on "Towards a European Strategy for the Security of Energy Supply" states that if nothing is done by 2030 the share of fossil fuels is expected to increase considerably.

The percentage of domestic energy supply to the overall energy demand decreased from 93% in 1950 to 28% in 2003. This situation is worse in fossil fuels; they only meet 16% of the energy demand of the country in 2003. The remaining amount is met by around 64.9 mtoe (million tons of oil equivalent) imported fossil fuels. Basic statistics of fossil fuel production and consumption in Turkey from 1950 to 2003 are given in Table 2 (WEC TNC, 1986, 1990, 2003). The biggest shares in imports are consisted of oil (34.0 mtoe), natural gas (18.9 mtoe), and bituminous coal (10.1 mtoe). Additionally, 1.8 mtoe coal products in the form of coke, petrocoke, and briquette are also imported.

Previously, it has been shown that a reduction of 1.663 billion US$ in fossil fuel cost can be made possible by increasing the domestic production of oil, lignite, and hard coal and by decreasing imports in Turkey (Çamdalı and Ediger, in Press). They also suggested giving priority to natural gas imports, if needed. However, the question as to what will be the future energy production of the country and the required imports remain to be answered. Since the production curves of all natural resources follow a Gaussian pattern, forecasting production of fossil fuels is a key issue for the decision makers on energy matters of the country. As properly noted by Saab et al. (2001), a sound forecasting technique is essential for accurate investment planning of energy production/generation and distribution.

Similar to most of the other countries in the world, forecasting is typically carried out for demand side of the energy system in Turkey. A comprehensive review and comparison of all previous energy demand forecasts done by government and academic institutions can be found in Ediger and Tatlıdil (2002). The details of a semi-statistical technique that makes use of any cyclicity in the historical data of annual additional amounts of energy demand is also given in this study, it has been a milestone in energy forecasting in Turkey. And from that date until now, only Canyurt et al. (2004) carried out a study on energy demand forecasting in Turkey. They employed a method called the quadratic form of Genetic Algorithm Energy Demand Model (GAEDM), which uses gross domestic product (GDP), population, import, and export figures as major variables.

Therefore, the main objective of this study is to forecast the most possible annual production curve by the technique that we developed for fossil fuel sources of Turkey and to compare them with the predicted consumption curve. In this study, hard coal, lignite, asphaltite, oil, and natural gas are taken into consideration as fossil fuels and forecasts are based on historical data from 1950 to 2003. This study includes advanced techniques such as ARIMA and SARIMA in addition to simple regression and a decision support system, which provides a comparison between these methods. However, in the previous study carried out by Hepbaşlı et al. (2002), only simple regression models have been applied to the bituminous coal, lignite, oil, natural gas, hydro, geothermal, and solar production data from 1970 to 1999.

2. Methodology

In this study, we developed a decision support system for forecasting fossil fuel production by using simple regression, ARIMA, and SARIMA in a comparative manner. The method integrates each model by using some decision parameters related to goodness-of-fit and confidence interval, behavior of the curve, and reserves.

Simple regression, which is the traditional way of time series analysis, has been used since late 19th century (Wei, 1994; Allen, 1997). A regression equation, which is an econometric model consisting of one equation, is obtained by using descriptive statistics such as means and variances. This equation may be simple as linear or complex as logarithmic, inverse, quadratic, cubic, compound, power, *S*, growth, and exponential. In this study Microsoft Office Excel database and SPSS statistical software are used to determine descriptive statistics, goodness-of-fit (R^2), regression equation, and forecasted values.

The ARIMA method, the autoregressive integrated moving average, is one of the most popular models in times series forecasting analysis (Ho and Xie, 1998; Zhang, 2001; Ho et al., 2002). The ARIMA method has been originated from the autoregressive model (AR), the moving average model (MA) and the combination of the AR and MA, the ARMA model, which was introduced in 1926, 1937, and 1938, respectively (Blanchard and Decrochers, 1984; Brown et al., 1984; Kamal and Jafri, 1997; Saab et al., 2001). Box and Jenkins (1976) provided a step-by-step procedure for ARMA analysis called ARIMA, which is a combination of AR coefficients, which are multiplied by past values of the time series data and MA coefficients, which are multiplied by past random shocks (Box et al., 1994, Mélard and Pasteels 2000, Tseng and Tzeng, 2002). In the ARIMA analysis, an identified underlying process is generated based on observations to a time series for generating a good model that shows the process-generating mechanism precisely (Box and Jenkins, 1976).

The only problem with ARIMA appears that the modeling is mathematically sophisticated in theory and requires a deep knowledge of the method (Ho and Xie, 1998; Mélard and Pasteels, 2000). Therefore, building an ARIMA model is often a difficult task for the user, requiring training in statistical analysis, a good knowledge of the field of application, and the availability of an easy to use but versatile specialized computer program (Mélard and Pasteels, 2000). For this, one of the commercial software packages, MINITAB and ITSM statistical software are used to construct an appreciate ARIMA model in this study. The ARIMA methodology includes identification (Abdel and Al-Garni, 1997; Chavez et al., 1999; Zhang, 2001), estimation (Abdel and Al-Garni, 1997), and diagnostic checking (Abdel and Al-Garni, 1997; Zhang, 2001; Brockwell and Davis, 2002). The SARIMA is seasonal time series ARIMA model. Other versions of ARIMA are CARISMA, a controlled autoregressive integrated segmented moving average model (e.g., Purkayastha, 1995), KARIMA, a hybrid method of short-term traffic forecasting (e.g., Van der Voort et al., 1996), FARIMA, a method which uses the fuzzy regression method to fuzzify the parameters of the ARIMA model (e.g., Tseng et al., 2001), and FSARIMA, a model which combines the advantages of the seasonal SARIMA model and the fuzzy regression model (e.g., Tseng and Tzeng, 2002).

This method is successfully used in forecasting various economic, marketing, and social variables. However, it has the limitation that at least 50 and preferably 100 observations or more should be used (Tseng and Tzeng, 2002). In our case, we have 54 observations from 1950 to 2003. So, we are at the limit and when more observations are taken the more accurate results can be obtained. Similarly, MINITAB and ITSM statistical software packages for the SARIMA model.

The application of regression techniques is widespread in various energy-related time series. On the other hand, the ARIMA model is most frequently used in forecasting of wind predictions (More and Deo, 2003), solid waste management (Navarro-Esbri et al., 2002), and electric energy consumption modeling (Abdel and Al-Garni, 1997). The only application of the ARIMA for energy production is by Chavez et al. (1999).

The flow chart of the Comparative Regression and ARIMA Method supported by a decision system are developed in this study is given in Fig. 1. We first applied various regression analyses to our time series data, such as linear, logarithmic, inverse, quadratic, cubic, compound, power, *S*, growth, and exponential. The data is obtained from the database of World Energy Council's Turkish National Committee (WEC TNC, 1986, 1990, 2003). We also performed ARIMA for each fossil fuel. We then filtered the result of the simple regression and ARIMA analyses through a decision support system to decide which model is to be used. This system includes three decision rules such as (1) goodness-of-fit and confidence interval, (2) behavior of the curve, and (3) reserves.

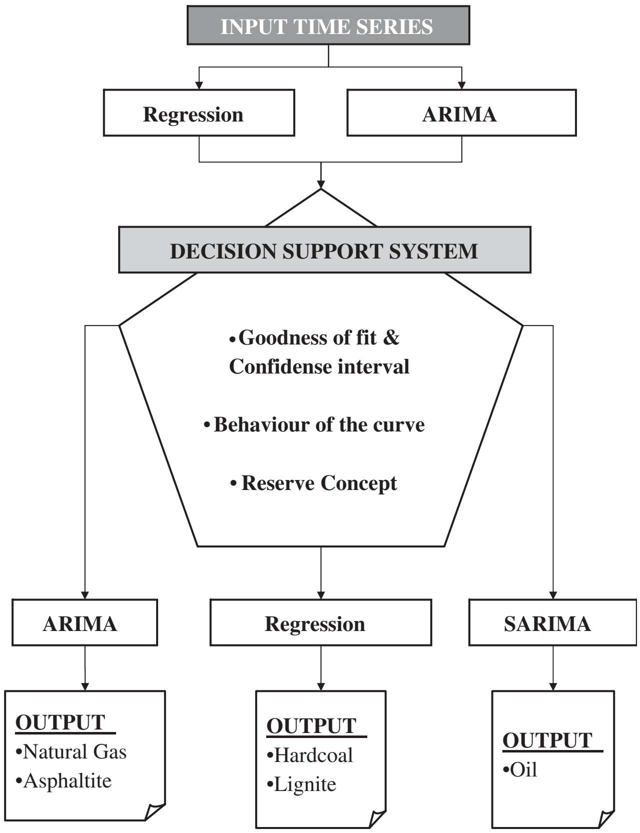

Fig. 1. Flow chart of comparative regression and ARIMA method.

2.1. Goodness-of-fit and confidence interval:

Goodness-of-fit (R^2) which is calculated based on prediction errors defined as the differences between observed values of the dependent variable and predicted values for the variable obtained, is the most important concept in regression analysis (Wei, 1994). The quality of regression analysis is best determined by examining R^2, which ranges from zero to one. Low R^2 value indicates a poor correlation while a high R^2 values represents a good correlation between the two variables, which are production values and time in our case. Therefore, we eliminated the regression models with poor goodness-of-fit.

On the other hand, the quality of forecast in the ARIMA model is related to the range of the confidence interval. Naturally, narrower this range, the more precise the forecast will be. In this study, 95% confidence interval is considered to reasonable determine the upper and lower limits of the forecast.

2.2. Behavior of the curve

The second parameter is the behavior of the production curve. The "rate-of-production curve" developed by Hubbert (1949, 1981) for any exhaustible resources are expected to fallow a Gaussian pattern. Such curves, *"after having reached one or more principal maximum, must eventually decline in a negative-exponential manner back to zero"* (Hubbert, 1981).

Therefore, the last years' trend in production curve of a fossil fuel can be used to determine whether the peak has already been reached or not. An increasing trend might indicate that the peak has not been reached yet whereas a decreasing trend might indicate that the peak has already been passed. Of course, the longer the time period of these trends, the more reliable the interpretations will be.

It is obvious that the cyclic patterns are also important for the behavior of the curve. In such cases, the SARIMA gives much better results than the ARIMA and the periodicity can best be determined by checking the autocorrelation function or visually by examining the cyclic patterns in the time series data. However, the interpreter should be confident that these types of patterns are not noises.

2.3. Reserves

The third parameter that should be considered is the reserve concept. It is clear that the forecasts should be compatible with the estimated reserves. The area under the "rate-of-production curve" of Hubbert (1981) is equal to "ultimate cumulative production" or "ultimate recoverable reserve".

The most complete data for the fossil fuel reserves of Turkey are available in the *Energy Statistics* published by the World Energy Council's Turkish National Committee as it is shown in Table 3 (WEC TNC, 1986, 1990, 1994, 1997, 1998, 2003). The major problem with the reserve data is that some vague terms such as "apparent", "probable", and "possible" have been used to classify coal and asphaltite reserves whereas oil and natural gas reserves are classified as "remained recoverable", which is synonymous to "proved reserve" of BP (2004).[1] It is also observed that the reserve estimations for various fossil fuels differ through time.

The most reasonable remained recoverable reserves of Turkish fossil fuel sources for 2003 are calculated based on available data in Table 4. Turkish lignite reserves have remained the same as 7 billion 339 million tons since 1993. The recoverable reserves are given for only 2 years, 1989 and 1993, which were 4,239,032,000 tons with a recovery factor of 61% and 3,907,958 tons with a recovery factor of 53%, respectively. Therefore, the recoverable lignite reserves can best be estimated as 3.908 billion tons for 2003.

Similarly, the hard coal reserves have remained the same as 428 million tons since 1996. WEC TNC statistics does not include the recoverable reserves but the TKİ (Turkish Coal Enterprises) experts claim that a recovery factor of

[1]BP (2004, p. 4) defines "proved reserve" as *"those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions."*

Table 3
Fossil fuel reserves of Turkey from 1986 to 2002 (WEC TNC, 1986, 1990, 1994, 1997, 1998, 2003)

	1986	1989	1993	1996	1998	2002
Lignite	5904.703	6946.518	7339.046	7339.046	7339.046	7339.046
Hard coal	174.849	145.784	185.089	428.000	428.000	428.000
Asphaltite	38.317	38.895	45.473	45.473	45.473	45.473
Oil	20.800	37.200	39.119	48.375	43.685	38.992
Natural Gas	15.012	13.060	9.807	8.762	8.880	10.218

Note: 1986 data is from WEC TNC (1986, p.107–110), 1989 data is from WEC TNC (1990, p. 107–110), 1993 data is from WEC TNC (1994, p. 91–96), 1996 data is from WEC TNC (1997, p. 75–80), 1998 data is from WEC TNC (1998, p. 55–59), 2002 data is from WEC TNC (2003, p. 55–59) (Natural gas is in billion cubic meters, others are in million tons).

Table 4
Remained recoverable reserves of Turkish fossil fuel sources for 2003

	Original Units	Aver. Calorific Value	Million toe
Lignite	3908.000 million tons	3000 kcal/kg	1172.40
Hard coal	364.000 million tons	6100 kcal/kg	222.04
Asphaltite	14.000 million tons	4300 kcal/kg	6.02
Oil	42.756 million tons	10500 kcal/kg	44.89
Natural Gas	7.952 bcm	9100 kcal/1000 m3	7.24
Total			1452.59

75% for underground mines and 90% to 100% for open-pit mines are quite possible. As an average, an 85% recovery factor can thus be taken. Therefore, 364 million tons is taken as recoverable hard coal reserves for 2003.

Asphaltite reserves have remained the same as about 45 million tons since 1993. The recoverable reserves are given as 14 million tons with a recovery factor of 30% in WEC TNC. Therefore, 14 million tons of recoverable reserve in 2003 is most possible for asphaltite. The remained recoverable reserves for oil and natural gas are taken from GDPA (2003, p.35 and 37).

3. Results and discussions

The summary of the descriptive statistics for each fossil fuel is given in Table 5. Figs. 2–6 show the regression model for hard coal and lignite, the ARIMA model for asphaltite and natural gas, and the SARIMA for Oil.

The highest goodness-of-fit values are found as 0.959 for lignite compound, growth, exponential, and logistic, as 0.957 for lignite cubic, as 0.932 for lignite quadratic and for hard coal cubic (Table 6). However, none of the forecasted curves of compound, growth, exponential, and logistic regression for lignite are similar to Hubbert's curve. For the asphaltite, oil, and natural gas none of the regression models appears to be suitable for their having low R^2 values.

Therefore, cubic regression seems to be the best model for hard coal forecast (Fig. 2). The reason why the ARIMA model is not chosen for hard coal is its having a wide 95% confidence interval. The only problem with this model arises from reserves. It is estimated from the curve that the total production from 2004 to 2018, RRR (Remained Recoverable Reserve), is equal to 5.974 mtoe. However, the remaining recoverable reserve of hard coal is estimated as 222.04 mtoe (see Table 4). Although the forecasted curve indicates a reserve much less than the already estimated values, the declining trend that continues for the last 29 years might indicate a reversal trend is quite impossible. However, provided that the estimated reserves are correct, new policy implications will be needed to reverse the trend by increasing production in the future. For the business as usual case, ultimate recoverable reserve will be much less than the estimated reserves.

Similarly, cubic regression model is found to be the best for lignite (Fig. 3). The reason why the ARIMA model has not been chosen in this case is that the forecasted curve is not similar to Hubbert's curve. The forecasted curve in the ARIMA model does not close up in the future. However, the same problem concerning reserves is also valid for lignite. Although the estimated reserves are 1172.40 mtoe, the "RRR" from 2004 to 2037 is equal to 340.919 mtoe. Similar to hard coal, the reserve estimations needs some revisions.

Asphaltite production data has a highly irregular time series (Fig. 4). Consequently, none of the method that has been utilized gave good results. ARIMA model was found to be more representative than the others but it does not obey the decision parameters. However, since its production values are small it does not affect the overall picture. Although, the forecast curve indicates that the production will continue but we cut it at 2038 and the Remained Recoverable Reserve (RRR) is calculated as 1.490 mtoe (Table 7) which is much smaller than the estimated reserves in Table 4.

ARIMA model is chosen for Natural Gas since it gave better results than regression analysis (Fig. 5). The results of the forecast are also more realistic, when compared to lignite, hard coal and asphaltite, because both the estimated reserves and "RRR" is equal to 7.2 mtoe (Tables 4 and 7).

The forecasting of future oil production has been the most successful one (Fig. 6). Since the cyclic behavior of oil

Table 5
Summary of descriptive statistics (thousand toe)

	N	Range	Minimum	Maximum	Sum	Mean	Standard deviation	Variance
Hardcoal	53	2038.90	1030.00	3068.90	117,400.30	2215.10	549.46	301910.20
Lignite	53	12,857.00	226.00	13,083.00	260,186.40	4909.18	4449.60	19,798,912.87
Asphaltite	37	365.30	4.70	370.00	4168.60	112.67	106.49	11,339.52
Oil	53	4655.10	18.90	4674.00	123,029.00	2321.30	1398.93	1,957,007.34
Natural gas	27	658.00	7.00	665.00	5025.00	186.11	179.94	32,376.64
Total fossil Fuels	53	15,818.00	2026.00	17,844.00	509,777.30	9618.43	5229.11	27,343,603.74

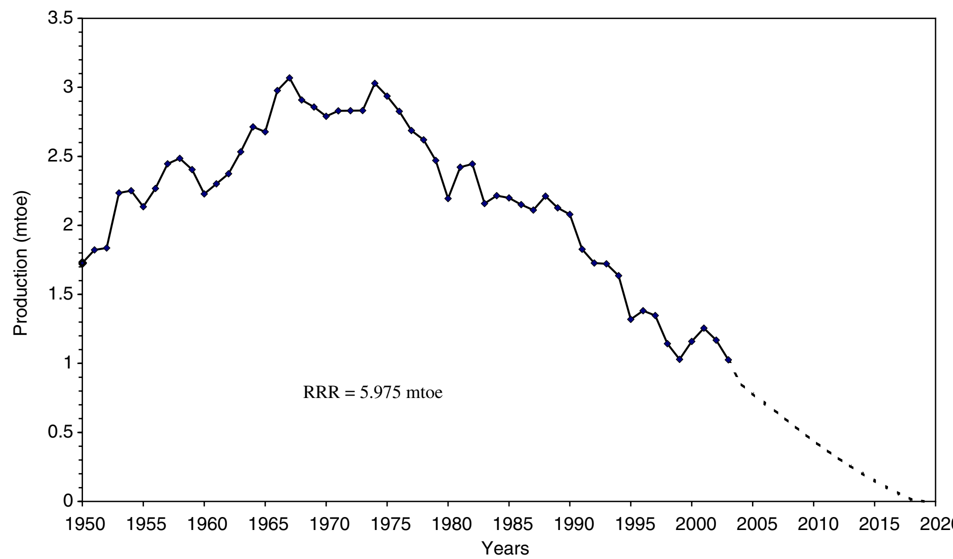

Fig. 2. Cubic regression model for hard coal.

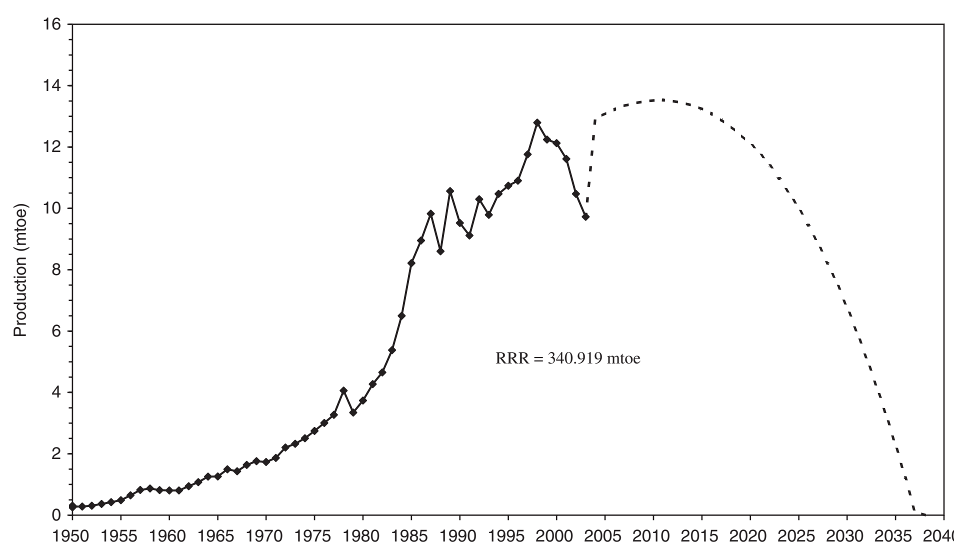

Fig. 3. Cubic regression model for lignite.

production curve well suits a seasonal model, SARIMA model is found to be the most applicable forecast method. The previously estimated reserves and "RRR" are equal to 44.9 mtoe (Tables 4 and 7). The forecast curve indicates that the production curve will make a third peak in 2018 and then will start to diminish until 2029.

According to the forecasted values for each fossil fuels and total in Turkey from 2004 to 2038 (Table 7), the

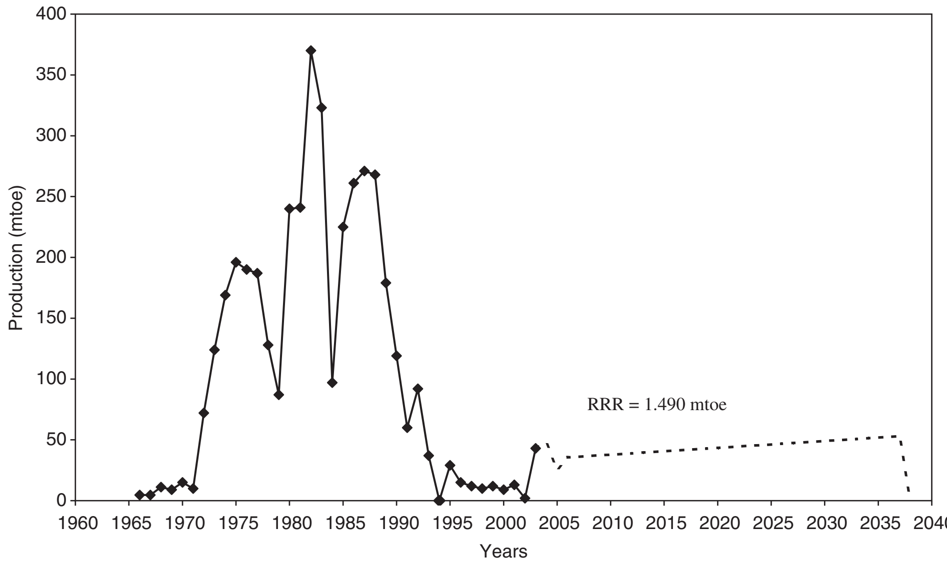

Fig. 4. ARIMA model for asphaltite.

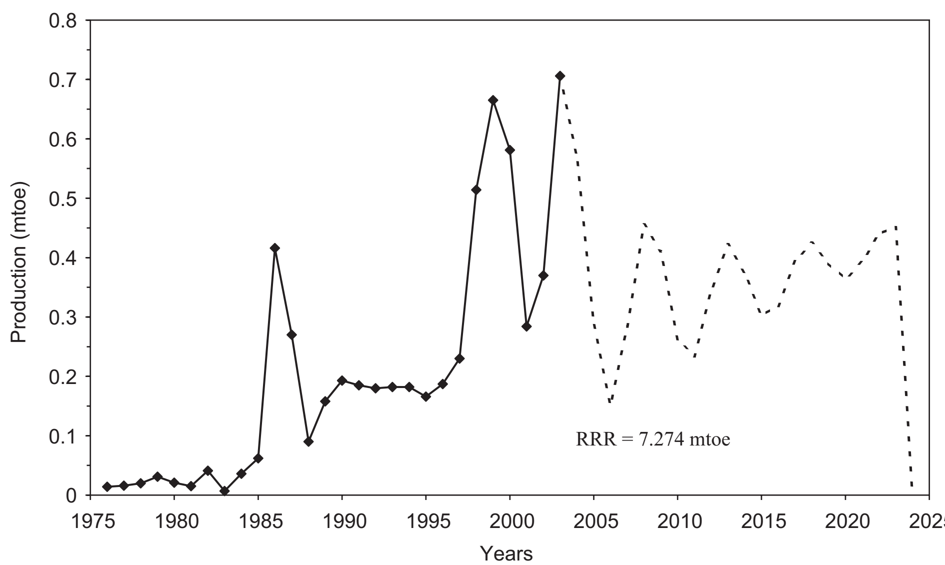

Fig. 5. ARIMA model for natural gas.

production will end in 2019 for hard coal, in 2024 for natural gas, in 2028 for oil, in 2038 for asphaltite, and in 2038 for lignite. As shown in Fig. 7 the overall fossil fuel production first increases until it reaches to a peak in 1998 and then starts to decrease until 2038 showing a typical Hubbert curve behavior.

Furthermore, an ARIMA model has been used for total fossil fuel consumption in order to investigate supply demand relation. According to Fig. 8 that shows the results of the fossil fuel supply and demand relation and the fossil fuel gap, the gap between the fossil fuel supply and demand will grow reaching 69 mtoe in 2010, 82.6 mtoe in 2020, and 103.4 mtoe in 2030. In other words, the percentage of fossil fuel consumption that will be met by the indigenous fossil fuel production will decrease to 18.64% in 2010, 15.52% in 2020, and 6.19%in 2030. This ratio falls from 80% to 19% throughout the period from 1950 to 2003, respectively. Therefore, effective policies should be developed on both demand and supply sides to decrease the dependency on imported fossil fuels. The importance of this observation can be well understood when the significant increase in percentage of fossil fuel consumption to the total energy consumption from 36% in 1950 to 88% in 2003 is taken into account.

4. Conclusions

This study shows that a comparative regression and the ARIMA method with a decision support system gives good results for forecasting of fossil fuel production.

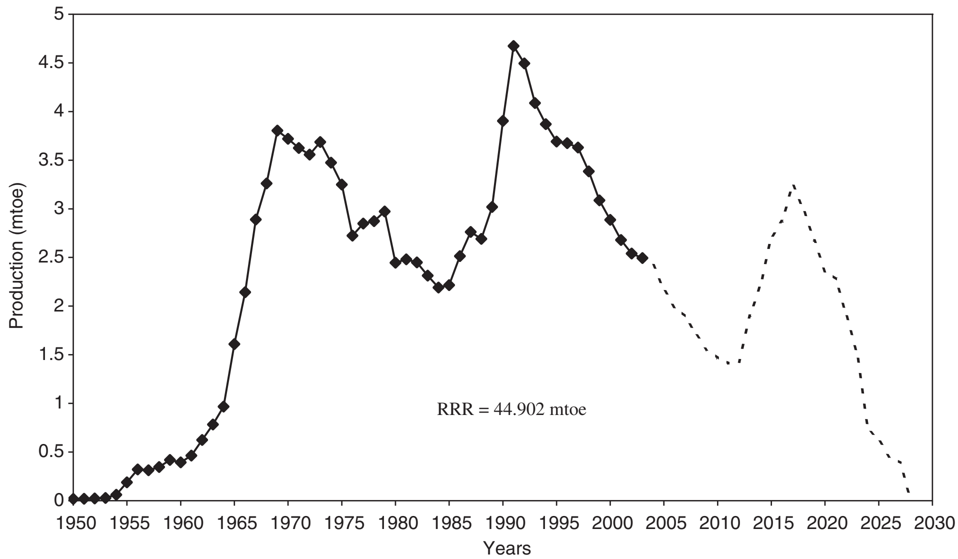

Fig. 6. SARIMA model for oil.

Table 6
Goodness-of-fits in various regression models

Fossil fuel	Regression types										
	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound	Power	*S*	Growth	Exponential	Logistic
Hardcoal	0.351	0.065	0.005	0.907	0.932	0.396	0.091	0.001	0.396	0.396	0.396
Lignite	0.894	0.6	0.171	0.932	0.957	0.959	0.885	0.392	0.959	0.959	0.959
Asphaltite	0.028	0.003	0.004	0.58	0.646	—	—	—	—	—	—
Natural Gas	0.628	0.596	0.556	0.667	0.67	0.768	0.783	0.783	0.768	0.768	0.768
Oil	0.57	0.657	0.316	0.743	0.743	0.564	0.864	0.634	0.564	0.564	0.564

Table 7
Forecasted fossil fuel production in Turkey from 2004 to 2038 (mtoe)

Years	Lignite	Hard coal	Oil	Natural gas	Asphaltite	Total
2004	12.936	0.855	2425.5	0.570	0.047	16.902
2005	13.093	0.782	2168.37	0.288	0.026	16.615
2006	13.228	0.710	1989.07	0.152	0.036	16.294
2007	13.339	0.640	1893.59	0.284	0.036	16.288
2008	13.425	0.571	1701.84	0.456	0.037	16.382
2009	13.485	0.504	1554.38	0.411	0.037	16.139
2010	13.518	0.439	1466.41	0.263	0.038	15.812
2011	13.522	0.376	1412.99	0.234	0.038	15.637
2012	13.498	0.316	1428.8	0.343	0.039	15.609
2013	13.442	0.258	1901.64	0.422	0.040	15.591
2014	13.356	0.203	2213.87	0.374	0.040	15.874
2015	13.236	0.151	2711.85	0.303	0.041	15.944
2016	13.083	0.101	2871.89	0.318	0.041	16.256
2017	12.894	0.055	3248.83	0.394	0.042	16.257
2018	12.670	0.013	2991.86	0.425	0.042	16.399
2019	12.409	0.000	2674.21	0.390	0.043	15.834
2020	12.110		2357.91	0.364	0.043	15.191
2021	11.771		2278.68	0.393	0.044	14.565
2022	11.392		1899.54	0.440	0.045	14.155
2023	10.971		1511.91	0.451	0.045	13.366
2024	10.508		733.28	0.000	0.046	12.065
2025	10.000		620.41		0.046	10.780
2026	9.449		456		0.047	10.116
2027	8.851		389.6		0.047	9.354
2028	8.206		0		0.048	8.643

Table 7 (*continued*)

Years	Lignite	Hard coal	Oil	Natural gas	Asphaltite	Total
2029	7.513				0.048	7.561
2030	6.771				0.049	6.820
2031	5.978				0.050	5.978
2032	5.134				0.050	5.134
2033	4.238				0.051	4.238
2034	3.287				0.051	3.287
2035	2.283				0.052	2.283
2036	1.222				0.052	1.222
2037	0.104				0.053	0.104
2038	0.000				0.000	0.000
Total	340.919	5.975	44.902	7.274	1.490	

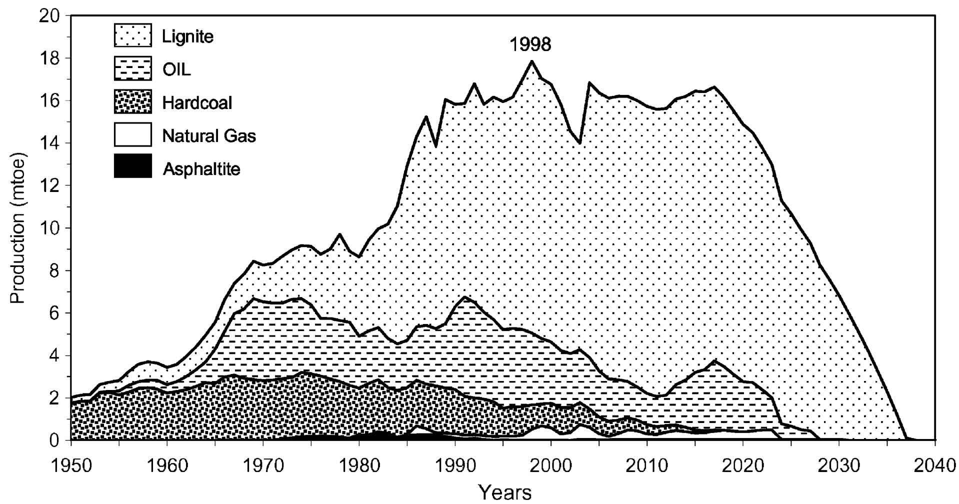

Fig. 7. Fossil fuel production in Turkey from 1950 to 2038.

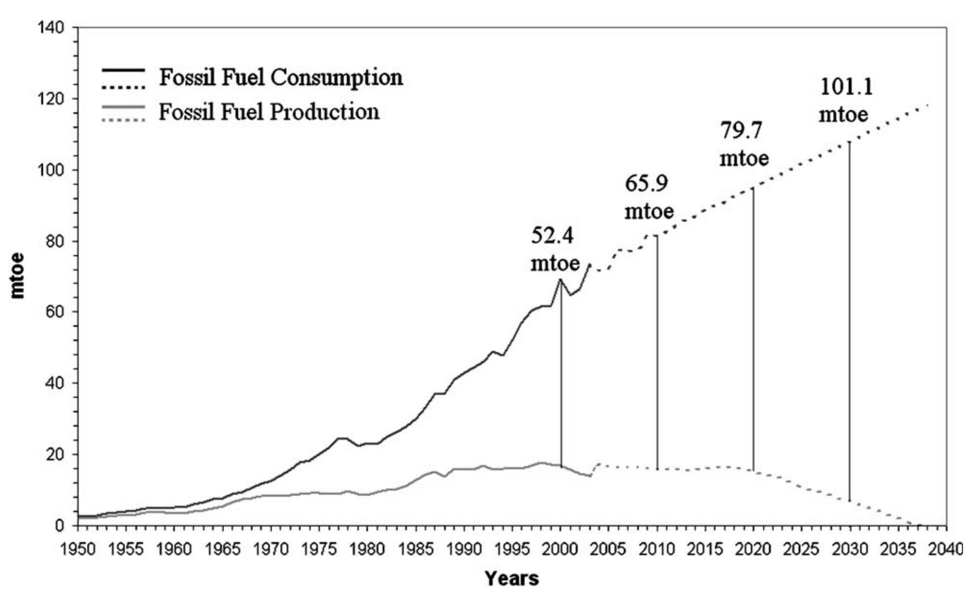

Fig. 8. Supply and demand relations of fossil fuels in Turkey.

Goodness-of-fit of regression and confidence interval of the ARIMA together with behavior of the curve and the reserve estimation increases the precision and reliability of the forecast models.

In this study, different forecasting models are proposed for different fossil fuel types for Turkey. The cubic regression model is used for hard coal and lignite, the ARIMA model is used for asphaltite and natural gas, and the SARIMA model is used for oil. Among them the best result is obtained for oil forecasting. One of the major reasons for this is that more modern reserve classifications have been used for these fuels than others. Therefore, it is here strongly suggested that the reserve estimation especially for coals should be revised.

The first major finding of the study is that the fossil fuel production peak has already been achieved according to the forecast results. This indicates that the total fossil fuel production of the country will be diminished and will theoretically be ended by 2038. However, it should be kept in mind that our forecast results of the ultimate cumulative production are much less than the already estimated reserves, especially for coals. It is obvious that when both the magnitude of production and reserves are taken into consideration, lignite outweighs the other fossil fuel sources and more efficient production policies of lignite may postpone the timing of the fossil fuel production peak.

Second important finding can be drawn from the fossil fuel supply and demand relation and the gap between them. This gap shows clearly that the dependence on imports is increasing and it will be filled with the imported fossil fuels, mostly in the form of oil and natural gas. Therefore, there seems to be two pathways for Turkey to follow for decreasing the fossil fuel gap in the future. On the demand side, policy programs should be prepared and decisively implemented to increase the energy productivity by substituting more efficient energy sources, by using energy more efficiently, and by switching from heavy industry to light industry and further to services in addition to energy conservation programs. On the supply side, production of domestic fossil fuel sources should be increased by employing more efficient methods and techniques if the reserve estimations are correct and by increasing reserves with the help of new discoveries.

Since the dependency problem on energy imports is international in scope and context and Turkey is a typical example for emerging energy markets of the developing world, the methodology used and the results are expected to be useful for the policy makers of other similar countries.

References

Abdel-Aal, R.E., Al-Garni, A.Z., 1997. Forecasting monthly electric energy consumption in Eastern Saudi Arabia using a univariate time series analysis. Energy 22 (11), 1059–1069.

Allen, M.P., 1997. Understanding Regression Analysis. plenum Press, New York and London.

Blanchard, M., Desrochers, G., 1984. Generation of autocorrelated wind speeds for wind energy conversion system studies. Solar Energy 33, 571–579.

Box, G.E.P., Jenkins, G.M., 1976. Time series analysis: forecasting and control. Holden Day, San Francisco.

Box, G.E.P., Jenkins, G.M., Reinsel, G.C., 1994. Time Series analysis forecasting and control, third ed. Prentice Hall Press, Englewood Cliffs, NJ.

BP, Statistical Review of World Energy (London: British Petroleum p.l.c, 2004)

Brockwell, P.J., Davis, R.A., 2002. Introduction to Time Series Forecasting. Springer Verlay Inc., New York.

Brown, B.G., Katz, R.W., Murphy, A.A., 1984. Time series models to simulate and forecast wind speed and wind power. Journal of Applied Meteorology 23, 1184–1195.

Canyurt, O.E., Ceylan, H., Öztürk, H.K., Hepbaşlı, A., 2004. Energy demand estimation based on two-different genetic algoritm approaches. Energy Sources 26, 1313–1320.

Chavez, S.G., Bernat, J.X., Coalla, H.L., 1999. Forecasting of energy production and consumption in Asturias (northern Spain). Energy 24, 183–198.

Çamdalı, Ü., Ediger, V. Ş., in press. Optimization of fossil fuel sources in Turkey: An exergy approach, Energy Sources.

Ediger, V.Ş., 2001. Efficient use of energy for economic and social development. Dünya Enerji 2 (14), 46–49 (In Turkish).

Ediger, V.Ş., 2003. Classification and performance analysis of primary energy consumers during 1980-1999. Energy Conversion and Management 44, 2991–3000.

Ediger, V.Ş., 2004. Energy productuctivity and development in Turkey. Energy and Cogeneration World 25, 74–78.

Ediger, V.Ş., Tatlıdil, H., 2002. Forecasting the primary energy demand in Turkey and analysis of cyclic patterns. Energy Conversion and Management 43 (4), 473–487.

GDPA (General Directorate of Petroleum Affairs), Petroleum Activities in 2003, Ankara.

Hepbaşlı, A., Oturanç, G., Kurnaz, A., Ergin, E., Genç, A., İyit, N., 2002. Simple correlations for estimating the energy production of Turkey. Energy Sources 24, 855–867.

Ho, S.L., Xie, M., 1998. The use of ARIMA models for reliability forecasting and analysis. Computers Industrial Engineering 35 (1–2), 213–216.

Ho, S.L., Xie, M., Goh, T.N., 2002. A comparative study of neural network and Box-Jenkins ARIMA modeling in time series predictions. Computers and Industrial Engineering 42, 371–375.

Hubbert, M.K., 1949. Energy from fossil fuels. American Association for the Advancement of Science 109 (2823), 103–109.

Hubbert, M.K., 1981. The world's evolving energy system. American Journal of Physics 49 (11), 1007–1029.

Kamal, L., Jafri, Y.Z., 1997. Time series models to simulate and forecast hourly averaged wind speed in Quetta, Pakistan. Solar Energy 61 (1), 23–32.

Mélard, G., Pasteels, J.M., 2000. Automatic ARIMA modeling including interventions, using time series expert software. International Journal of Forecasting 16, 497–508.

More, A., Deo, M.C., 2003. Forecasting wind with neural Networks. Marine Structures 16, 35–49.

Navarro-Esbri, J., Diamadopoulos, E., Ginestar, D., 2002. Time series analysis and forecasting techniques for municipal solid waste management. Resources, Conservation and Recycling 35 (3), 201–214.

Purkayastha, D.D., 1995. An exposition of the decomposition in a controlled autoregressive integrated segmented moving average (CARISMA) model. Economic Letters 48, 1–7.

Saab, S., Badr, E., Nasr, G., 2001. Univariate modeling and foracsting of energy consumption: the case of electricity in Lebanon. Energy 26, 1–14.

Tseng, F.M., Tzeng, G.H., Yu, H.C., Yuan, B.J.C., 2001. Fuzzy ARIMA model for forecasting the foreign excahnge market. Fuzzy Sets and Systems 118, 9–19.

Tseng, F.-M., Tzeng, G.H., 2002. A fuzzy seasonal ARIMA model for forecasting. Fuzzy Sets and Systems 126, 367–376.

Van der Voort, M., Dougherty, M., Watson, S., 1996. Combining Kohonen maps with ARIMA time series models to forecast traffic flow. Transpiration Research C 4 (5), 307–318.

WEC TNC (World Energy Council Turkish National Committee), 1986. Energy Statistics, Ankara, pp. 107–110.

WEC TNC (World Energy Council Turkish National Committee), 1990. Energy Statistics, Ankara, pp. 97–101.

WEC TNC (World Energy Council Turkish National Committee), 1994. Energy Statistics, Ankara, pp. 91–96.

WEC TNC (World Energy Council Turkish National Committee), 1997. Energy Statistics, Ankara, pp. 75–80.

WEC TNC (World Energy Council Turkish National Committee), 1998. Energy Statistics, Ankara, pp. 55–59.

WEC TNC (World Energy Council Turkish National Committee), 2003. Energy Statistics, Ankara, pp. 55–59.

Wei, W.W.S., 1994. Time Series Analysis. Addison-Wesley Publishing Inc., USA and Canada.

Zhang, G.P., 2001. Time series forecasting using a hybrid ARIMA and neural network model. Neurocomputing 50, 159–175.